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SPORT RELATED OSTEOARTICULAR ALTERATIONS IN CHILDREN AND ADOLESCENTS

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Abstract

Recent expansion of sport and strength training among children and adolescents inspire for special concern about possible risks associated with this phenomenon. An alarming finding is the growing number of reports of the stress related bones and spine injuries affecting young athletes that may result in significant growth disturbance and deformity. This article elucidates sport related osteoarticular alterations, possible risk injury factors and countermeasure recommendations for children and adolescents training.

Key words: *sport, children training, adolescents training, articular, vertebral column, bones*

Introduction

The children's and youth participation in sports is widespread in modern culture. Many youngsters initiate year round training and specialization in particular sports at very early age. Increased involvement and difficulty of skills practiced at the early age and continuation throughout the period of growth with high level of intensity required to be competitive implies the concern about the risk and severity of injury for young athletes. Both the acute and chronic bones and spine injuries related to participation in sports have been reported but the information of their circumstances are limited. The growing number of stress related injuries concerns those affecting the extremities and spine. Although most injuries appeared to resolve with treatment and rest there is an evidence of growth disturbance and deformity. The aim of this study was to present the effects of training programs on pre- and early-pubertal youth in terms of potential influence on growth, maturation and occurrence of injury.

Despite the belief that sport training was dangerous or ineffective for children, the safety and effectiveness of youth sport training are now well documented (1, 2). The significant concern is that the growing children's bones could be less resilient and less resistant to physical stresses than the adult ones (3). However low-back injury continues to be the greatest clinical concern, especially in weight lifters and power lifters. Individuals involved in strength training are at risk for both lumbar flexion- and torsion-related injuries (e.g., forward displacement of one vertebral body over another that leads to spondylolisthesis, herniated intervertebral disc, paraspinous muscle strain) and lumber extension-related injuries (e.g., facet syndrome, pars interarticularis stress fracture, spondylolysis). However, there is no evidence that strength training is riskier than participation in youth sporting and recreational activities (4). Most of these injuries occur as the result of improper training, excessive loading, and lack of qualified adult supervision and could be avoided by proper sport training schedule (3, 5). To design and administer a sport training program appropriate for young children and adolescents, it is imperative to understand the unique anatomical and physiological nature of children spine and epiphyses.

Anatomy and physiology of the bones and spine

The growing parts of the bone include the physis and the epiphysis. Two types of epiphyses are found in the extremities: traction and pressure. Traction epiphyses (or apophyses), such as apophysis of the tibial tubercle, are located at the site of attachment of major muscle tendons to bone and are subjected primarily to tensile forces. The apophyses contribute to bone shape but not to longitudinal growth (6), therefore, acute or chronic injuries affecting traction growth plates are not generally associated with disruption of longitudinal bone growth. Overuse apophyseal conditions, such as Osgood-Schlatter disease, Sever's disease and medial epicondylopathy in the throwing arm are commonly found in young athletes. Whereas pressure epiphyses are situated at the end of long bones and are subjected to compressive forces. The epiphyses of the distal femur and proximal tibia provide examples. The growth plate or physis is located between the epiphysis and metaphysis and is the essential mechanism of endochondral ossification (7). In contrast with traction growth plates, injury to pressure epiphyses and their associated growth plates may result in growth disturbance. Longitudinal growth is accomplished by the proliferation of germinal cells in the "zone of 'growth". These cells are attached to the epiphysis and obtain their vascular supply from the epiphyseal artery. The zone of growth is the area of greatest concern with any fracture involving the growth plate, as damage to cells in this zone may have long term consequences for normal growth patterns. The next functional area is the zone of cartilage ''maturation". Increased extracellular matrix is formed in this zone, primarily between columns. The extracellular matrix exhibits cell mediated biomechanical changes, then calcifies. The cells align in vertical columns as they hypertrophy and are eventually replaced by osteoblasts. Fractures most commonly occur at the junction of calcified and uncalcified hypertrophic cells because it is structurally the weakest portion of the growth plate (7, 8). In the zone of cartilage ''transformation", the cartilaginous matrix is penetrated by metaphyseal vessels, which break down the transverse cartilaginous septa, allowing invasion of mature cell columns. The cartilage and the bone are remodelled, removed and replaced by a more mature, secondary spongiosa, eventually containing no remnants of the cartilaginous precursor (7, 8). Irreversible damage to the growing cells may be produced by physeal injuries, resulting in growth disturbance. Growth plate cartilage is both less resistant to stress than adult articular cartilage and less resistant than adjacent bone to shear and tension forces (9, 10). Therefore, when disruptive forces are applied to an extremity, failure may occur through the physis. Research shows that the physis may be 2-5 times weaker than the surrounding fibrous tissue (11). For these reasons, injury mechanisms that in an adult may result in a complete tear of a ligament or in a joint dislocation may produce a separation of the growth plate in a child (8). The growth plate appears to be especially susceptible to injury during periods of rapid growth (7, 9, 12, 13). An increase in the rate of growth is accompanied by structural changes that result in a thicker and more fragile plate (14). Furthermore, bone mineralization may lag behind bone linear growth during the pubescent growth spurt, rendering the bone temporarily more porous and more subject to injury (15). Increased incidence of fractures during pubescence has been reported in human physeal injuries studies, with the peak fracture rate probably occurring at the time of peak height velocity (12, 14, 15). Presumption that the growth spurt may also increase susceptibility to growth plate injury by causing an increase in muscle-tendon tightness about the joints and an accompanying loss of flexibility remains controversial (16, 17). A temporary disparity between muscle-tendon and bone lengths appears as a result of initial longitudinal growth in the long bones of the extremities and subsequent muscle-tendon units elongation. Application of excessive muscular stress may produce muscle-tendon imbalance and increase in susceptibility to injuries (18). It is claimed that the joint, and in particular the growth cartilage, as the weak link in this assembly, may increase the risk of injury at this site during the growth spurt (16).

The vertebral column consists of the seven cervical vertebrae, the twelve thoracic vertebrae, and the five lumbar vertebrae, perched upon the sacrum and pelvis. The structure and function of each segment of the spine is specific to demands placed upon it anatomically and physiologically. The vertebrae of the neck have demands for both range of motion and structural integrity. The majority of the 'overuse injuries' of the cervical spine are the result of a combination of discogenic and facet deterioration and arthrosis with secondary bony overgrowth and impingement. Impingement, as noted, is generally that of the exiting nerve roots, but sometimes a frank myelopathy may occur. Sport related injuries of the thoracic spine are relatively rare, and this is undoubtedly related to the structure and function of the thoracic spine, characterized by normal posterior angulation, or kyphus, which varies normally between 20° and 40° (19). Despite the sparseness of direct injury of thoracic spine elements from repetitive sport overuse, its indirect contribution to overuse injuries in both cervical and lumbar spine may occur. Major components of lumbar motion, as well as the concentration of relative stresses in the lumbar spine, occur near the base from the L3-L4 juncture through L5-S1. This in turn is reflected in the pattern of degenerative changes seen from repetitive activity in the lumbar spine, where the alterations are localized mainly at the level of L5-S1, followed sequentially by L4-L5 and L3-L4 (20).

The spine in the adolescent differs from that of an adult in numerous respects. At a Risser stage 1, the iliac apophysis has not yet formed and the spine is immature. At a Risser stage 4 the entire apophysis has formed but has not united with the pelvis. This stage corresponds to the end of spinal growth. In the immature spine the facet joints are more horizontal and incompletely ossified, which results in more spinal mobility. They achieve a mature configuration by 8 years of age, but the full, more oblique adult pattern is not seen until 15 years of age (21). The epidural sac ascends to its normal level opposite L1 in the spinal canal by 1 year of age and the spinal canal attains adult volume by 6 years of age (22). The physes of immature growing spine appear radiographically between 8 and 12 years of age when the vertebral apophyseal ossification begins to develop in the periphery of the cartilaginous end plates. Early in their development they appear as rings because they are thicker at the periphery than at the centre. The ring apophysis contributes to vertebral body breadth and the physeal portion contributes to the vertical height. The fusion of end plates begins at the age of 14 to 15 years and may be confused with fractures until it finishes at 21 to 25 years of age. If the end plate is damaged or changed, or partially fused, an increase in deformity may occur, especially during the rapid adolescent growth spurt. Aufdermaur's studies reported that fractures of the immature spine traverse the growth zone of the physis similar to long bone physeal fractures (23). Physeal closure and cessation of spinal growth result in decline of weak zone existence in the spine, therefore the failure occurs then through the bony vertebral body or the annulus fibrosus and the disc space. The immature intervertebral disc as more hydrophilic than the mature disc presents as more effective shock absorber between the vertebral bodies, which implies its marked resistance to injury (21).

Sport related physeal and spinal injuries

Acute and chronic physeal injury

Acute physeal injuries were classified by Salter and Harris, whose classification system distinguishes 5 types of growth plate injury (24). Type I injuries show a complete separation of the epiphysis from the metaphysis without any bone fracture. The germinal cells of the growth plate remain with the epiphysis, and the calcified layer remains with the metaphysis. In type II, the most common physeal injuries, the line of separation extends along the growth plate, then out through a portion of the metaphysis, producing a triangular shaped metaphyseal fragment sometimes referred to as the Thurston Holland sign. Type III, which is intra-articular, extends from the joint surface to the weak zone of the growth plate and then extends along the plate to its periphery. In type IV, often involving the distal humerus, a fracture extends from the joint surface through the epiphysis, across the full thickness of the growth plate and through a portion of the metaphysis, thereby producing a complete split. In type V, a relatively uncommon injury, there is a compression of the growth plate, thereby extinguishing further growth (8). Prognosis for types I and II fractures is good if the germinal cells remain with the epiphysis, and circulation is unchanged. However, these injury types are not as innocuous as originally believed, and can be associated with risk of growth impairment (7, 25). Type III injuries have a good prognosis if the blood supply in the separated portion of the epiphysis is still intact and if the fracture is not displaced. Surgery is sometimes necessary to restore the joint surface to normal. In type IV injuries, surgery is needed to restore the joint surface to normal and to perfectly align the growth plate. Type IV injuries have a poor prognosis unless the growth plate is completely and accurately realigned (8).

The physis is involved in approximately 15% of all fractures in children (7) . Many childhood misadventures, such as those incurred by falling off bicycles, skateboards, playground equipment, out of trees result in acute growth plate injuries. Competitive sports (e.g. hockey, football, baseball) accounted for 33.5% and recreational activities (e.g. biking, skateboarding, skiing) for 21.7% of physeal injuries. Several studies reported that organized sports accounted for more physeal injuries than recreational activities (12, 26-29). Although American football is predominantly associated with acute physeal fractures, most other sports are also represented (12, 13, 30). Chronic physeal injury can also appear as a result of sport training of sufficient duration and intensity and these pathological changes of the growth plate in extreme cases produce growth disturbance. This injury appears to occur through repetitive loading, which alters metaphyseal perfusion and in so doing interferes with the mineralization of the hypertrophied chondrocytes, which typically occurs in the zone of provisional calcification (7). The hypertrophic zone continues to widen because of constant growth in the germinal and proliferative zones, the widening of the growth plate within the hypertrophic zone is usually temporary, as the resting and dividing cellular layers of the growth plate, and the attendant epiphyseal and metaphyseal blood supplies, are essentially undisturbed. However, in some situations, this ischaemic condition may lead to osseous necrosis and deformity within the developing ossification centre and to growth irregularities in the physis. These changes may be localized and cause asymmetric growth, or they may involve the entire physis and result in an overall slowdown of the rate of growth or even complete cessation of growth. In either case, premature closure of some or all of the physis may occur (7). The most commonly reported physeal stress injuries have been those affecting the distal radial physes of young gymnasts. Almost all patients with stress related injury affecting the distal radius recover with rest, and do not experience premature physeal closure or abnormal growth. However, there are several reports of distal radius physeal arrest in skeletally immature female gymnasts (31-34).

Spinal injury

Injuries to the spine are rare in young children but increase significantly in adolescence. The majority of spine insults in the pediatric population occur in children aged 14 to 16 years of age (22). The most frequently injured area of the spine is T4 to T12, followed by T12 to L2 (35). Hadley and al. (35) found that sport activities were the third cause of spinal fractures in children aged 10 to 16 years, although most reviews of sports-related injuries show a relatively low incidence of specific injuries to the spine. The majority of spine complaints in the athletically active individuals are secondary to chronic overuse injuries resulting in repetitive microtrauma to the thoracolumbar spine. There are 3 main mechanisms of spinal injury seen in children: flexion, with or without compression; distraction; and shear (36). Acute fractures of the pars interarticularis are usually the result of repetitive hyperextension stresses in gymnastics, weight lifting and football but may occur after relatively minor trauma in a previously weakened area (21). It is imperative that the physician dealing with young sportsmen should be aware that the pattern of injury and back pain in an athlete is quite different from that in a non-athlete. Failure to appreciate the difference between the pattern of diagnosis and the structures injured in the athlete in contrast with the general population results in many misdiagnoses and delays in diagnosis which may have a serious impact not only on athletic performance but also on the future potential for healing in a number of these injuries (19). Acute traumatic injuries to the spine are the result of direct blows, twists, or sudden applications of force and may ultimately be diagnosed as acute traumatic fracture or dislocation, as well as sprain of the ligamentous structures of the spine requiring emergency medical treatment. However training phase of sports participation is particularly associated with overuse injuries which appear as result of repetitive activity (19).

Facet tropism

Facet tropism can generally be classified as an overuse syndrome associated with hyperextension sporting activities. It is a condition which is characterized by a variation between the angulation of the facet joint facings between the left and right sides of the same vertebral segment and is a most frequent cause of back pain in athletic teenagers. The condition appears to be exacerbated by any sport such as basketball or volleyball which can cause sudden forceful hyperextension of the lumbar spine. In this condition, the loss of bony stabilization of the facet joints is thought to predispose to consequent stretching and irritation of the ligamentous capsules. The resulting inflammation of the capsular ligaments is thought to be responsible for the onset of symptoms, mainly pain with movement. Treatment involves specific exercises to strengthen the lumbar musculature and thereby provide additional support. Exercises which involve hyperextension of the lumbar spine, beyond the neutral position, should be avoided as they will tend to aggravate the patient's problem. The problem usually resolves in early adult life, but may return again in the third or fourth decade as the patient's muscle tone undergoes that all too common phase called "deconditioning" (37).

Spondylolysis

Approximately 6 per cent of adults in the general population have evidence of spondylolysis and the mean age of the symptomatic population is between 15 and 16 years of age. Eighty-five per cent of the lesions occur at the L5 vertebral level (38). In the young athletic population the mechanical injury to the pars interarticularis appears as the most frequent anatomical lesion described as a stress fracture resulting in a bony defect at one or both sides of a given vertebral level (39, 40) Defects of the pars interarticularis have generally been classified into dysplastic, isthmic (traumatic), and degenerative types. The pathogenesis of this lesion in athletes is believed to be due to microtrauma and resultant stress fractures of the posterior elements of the spine rather than a congenital condition (39, 40, 41). Biomechanical studies shows that shear stresses across the pars interarticularis are increased when the spine is extended and accentuated with lateral flexion manoeuvres from a hyperlordotic posture (41). Athletes exposed to repetitive traumatic stresses on the lumbar spine, as is seen in blocking and sled training in American football, or performing specific repetitive lumbar motions, as seen in ballet dancing, competitive diving, pole vaulting, hurdling, and gymnastics have been frequently found to be prone to vertebral lesions (19). The coincidence of onset of pain with the adolescent growth spurt essentially directs for spondylolysis enquiry. Spondylolysis in the sportsmen is generally a mechanically stable lesion, and the usual problem for the patient is the potential for activity-related pain rather than spine instability, particularly when stresses are placed across the posterior elements of the spine. Patients eventually complain of severe pain, which becomes associated with daily activities. The current initial management consists of a restriction of activities and immobilization of the lumbar spine with a rigid polypropylene antilordotic lumbosacral brace. Athletes who are unable to be weaned from their brace without a recurrence of their symptoms may require surgery. A posterolateral transverse process fusion is the classic form of treatment, although direct osteosynthesis of the lesion has been described (20, 42).

Spondylolisthesis

Spondylolisthesis occurs as a vertebral body slips forward on the one below it, subsequent to a pars interarticularis defect (19). Spondylolisthesis has three predisposing factors: 1. traumatic defect in the pars interarticularis of the neural arch, known as spondylolysis, 2. congenital malformation, especially elongation of the articular processes, and 3. degeneration of the posterior facet joints (37). The dysplastic type, which features spondylolysis with malformed or dystrophic posterior elements, has a much higher incidence of slippage than the isthmic type seen in the athletic population. It is most frequently noted in nonathletic females during their adolescent growth spurt between 10 and 15 years of age. The L5-S 1 vertebral level is involved in 85 to 90 per cent of cases. A genetic predisposition to spondylolisthesis has been suggested in several studies. The incidence of high grade spondylolisthesis (more than 75 per cent slippage) is much higher in females than in males (43, 44). No athletic restrictions have been recommended for patients with less than 30 per cent asymptomatic spondylolisthesis and their ability to participate in contact sports has been claimed. Significance of conservative program of physical therapy for patients with minimal symptoms should be emphasized as well as modification of their sports activities. Brace management with a rigid antilordotic polypropylene lumbosacral orthosis is carried out for 3 to 6 months in those patients who fail initial treatment with physical therapy. Between 30 and 50 per cent of spondylolisthesis in skeletally immature patients should be closely followed for signs of progression. Surgical management is reserved for those patients whose vertebral slippage increases over 50 per cent and posterior in-situ fusion is the procedure of choice. Contact sports are contraindicated after lumbar fusion (20, 42).

Scheuermann's disease

Development of roundback deformity may be found in some adolescents as mechanism of compensation for tight lumbodorsal fascia and hamstrings. This kind of deformation is often transient, although some patients may expand anterior wedging of the vertebral bodies (45). When three or more vertebra are wedged more than 5° the Scheuermann's disease radiographic criteria are fulfilled (46). Taking the athletes population into consideration classic Sheuermann's disease, also known as juvenile thoracic kyphosis, is quite rare (45, 47). In contrast, 'atypical' or lumbar Scheuermann's disease presents with irregular vertebral end-plates at the thoracolumbar junction and is seen more frequently in the athletic population. This form of the disease is painful and is associated with activities that produce repetitive microtrauma to the thoracolumbar spine. In young athletes, especially those adolescents performing repetitive flexion/extension of the spine in very rigorous training programs, such as rowers and gymnasts, a radiographic picture, which resembles the wedged vertebra and irregular vertebral end-plates seen in thoracic Scheuermann's disease, is sometimes obtained in the mid-thoracic to the mid-lumbar spine (47). The peak age is between 15 and 17 years and there is a 2:1 male predominance. Repetitive flexion and extension of the thoracolumbar junction results in multiple growth-plate fractures and secondary bony deformation of the vertebra. Apophyseal fragments at the anterior margin of the vertebral body may be avulsed, resulting in Schmorl's node formation and irregular vertebral end-plates (19). The treatment strategy includes rest, avoidance of the inciting activity and non-steroidal anti-inflammatory drugs (NSAIDs) for persistent symptoms management. A bracing regimen may be instituted using a semirigid thermoplastic brace with 15° of lumbar lordosis to immobilize the patient until remodeling is seen on plain radiographs. Patients may return to sports while they are braced and are prescribed a flexibility program. No restrictions are placed on the patients when they are weaned from their brace. Surgical intervention is rarely indicated in these patients (19, 48).

Management

The rehabilitation of spinal injuries in the athletic population constitutes a complex therapeutic challenge while only a few of these patients eventually require surgical intervention. Most of them are not sufficiently debilitated from their injuries to refrain from normal daily activities, yet their athletic performance and enjoyment is significantly restricted. The ultimate goal for the physician is to return the patient safely to the repetitive demands of athletics in a pain-free state as quickly as possible without exacerbating the problems. In the case of spinal rehabilitation, clear initial goals must be set regarding the time course of immobilization and rehabilitation for each problem. The significant role of pain reduction subsequent to increase in endorphin levels associated with exercises and the maintenance of aerobic cardiovascular fitness in the prevention and rehabilitation of lumbar spine problems should be emphasized (19). Thermoplastic antilordotic thoracolumbar spine braces, such as the Boston brace, allow patients to resume light sports activities while wearing the brace. However, it must be accentuated that all brace prescriptions are accompanied by a physical therapy program designed to strengthen the abdominal musculature and increase flexibility of the spine and hips (19, 48). Coaches and others associated with children's and youth sports should be educated about the potential for growth plate injury and recommended strategies for prevention. The following preventive measures may be worthy of consideration.

- Training and skill development should be individualized to reduce risk of acute and stress related injury. Reduction of training loads and delay of skill progressions for young athletes experiencing periods of rapid growth must be taken into consideration.
- A variety of drills or activities during practice should be used to avoid excessively repetitive movements that may result in overuse injury.
- It is recommended to perform physical examination periodically so that stress related growth plate and other overuse injuries could be diagnosed at an early stage and modifications in the training program should be administered as soon as they become indicated.

– Physical conditioning, including strengthening, range of motion, and proprioceptive exercises, may help to reduce both acute and chronic physeal injury.
– Periodisation of training may also help to reduce stress related physeal injuries and prevent overtraining. This technique involves the systematic cycling of training loads over set periods of time with well defined rest periods.
– When acute epiphyseal fracture involves a joint, it is recommended that the child not participate in contact sports for at least four to six months to prevent reinjury.

Finally, there is unarguable necessity of proper communication between the coach and the sport medicine specialist. Young athletes should be assessed at the first opportunity just when they start to develop symptoms. Severe pain around a joint with sudden or gradual onset may be the symptom of significant growth plate affection which require examination by a doctor, prompt treatment and specific recommendations about return to sport activity (8).

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